New York State Department of Transportation STRUCTURES DIVISION		
STRUCTURES DESIGN ADVISORY		
ISSUED BY: **MAIN OFFICE STRUCTURES DIVISION**	**SUBJECT: GUIDANCE FOR FRP REPAIR AND STRENGTHENING OF CONCRETE SUBSTRUCTURES**	**CODE: 02-002** **DATE: Sept. 6, 2002**
APPROVED BY:		**SUPERSEDES:** **None**

BACKGROUND:

FRP materials have been used by the Department on an experimental basis to repair or strengthen concrete substructures. The short term performance of these materials has been satisfactory. Designers may consider their use as an alternative or supplement to traditional concrete repair and strengthening methods with DCE(S) approval (early DCE(S) notification of the intent to use FRP's will facilitate the approval process) . There are two basic types of FRP materials in use for concrete structure applications: E-glass or carbon fibers. Carbon fiber FRP is stronger, but is more costly than E-glass. Both types of FRP systems are on the Department's Approved List of Materials and Equipment.

FRP materials offer significant advantages over conventional concrete repair. Foremost is their ease of application without the use of heavy equipment or time consuming forming. Although long term data is not yet available, FRP repairs are expected to provide a longer service life than conventional concrete repairs. Cost data for FRP repairs is not yet extensive, but they can be estimated to be approximately $125 per layer per square meter for E-glass and $175 per layer per square meter for carbon.

STRUCTURAL REPAIR AND STRENGTHENING APPLICATIONS:

FRP materials applied to sound concrete are considered to be a long term repair and the design life is the expected remaining life of the bridge element. This would most often be the case of a seismic retrofit or the correction of an original design deficiency. The determination of sound concrete should include a finding that the half cell corrosion potential is less negative than -0.2 volts. The repair is considered temporary if the half cell potential is more negative than -0.2 volts,. However, it is possible to remove chlorides and reduce corrosion potential through a procedure known as Electro-Chemical Chloride Extraction (ECE). ECE can be expected to be effective for approximately 15 years. Therefore, for long term repairs to be effective, the future ingress of chlorides must be addressed.

Concrete columns can be reinforced with an FRP wrap to improve concrete confinement and shear strength. FRP materials have been found to be more efficient in retrofitting round columns than rectangular columns, although FRP wraps can be applied to

rectangular columns when the aspect ratio (length to width in cross section) does not exceed 1.5, corner chamfers are rounded to a radius of 25 mm and a reduced confinement force is accounted for in the design.

Reinforced concrete flexural members such as pier capbeams can also utilize FRP materials to improve bending and shear strength. FRP systems are designed to restore specific capacities (positive moment, negative moment, shear etc.), by taking into account fiber ratio, fiber orientation, manufacturing type and bonding materials.

Deteriorated concrete can also be repaired with FRP's although this use is more problematic. The application of an FRP wrap will not stop the corrosion of steel reinforcing bars in concrete containing chlorides where water continues to infiltrate. If the cause of the concrete deterioration is not addressed (e.g. leaking deck joints), the FRP repair should be considered a temporary fix that may provide an additional 5-7 years of service life for the structure. Measures to address the cause of concrete deterioration should accompany the use of FRP materials. Long term repairs should be designed for a minimum service life of 20 years, or longer on a relatively new bridge which does not exhibit any signs of distress. Appropriate strength reduction factors are used to account for the design service life.

Trapped water can lead to future deterioration of the encased concrete and reinforcement. For this reason total encasement of a structural element should be avoided for permanent repairs.

FRP materials are susceptible to degradation from ultraviolet radiation, particularly those that contain E-glass fibers or epoxy resin. Therefore, specifications require all FRP installations to be coated with a UV protective coating system. It is expected that recoating will be required during the life of long term repairs.

Regional Bridge Maintenance Engineers must consider all FRP wraps used on NYSDOT bridges to be a structural repair that must be designed, reviewed, and administered accordingly. The use of FRPs for short-term repairs alleviates long-term concerns of product durability and environmental degradation. Nonetheless, significant other concerns regarding FRP application, design procedures and review, product variability, surface preparation requirements, bond criticality, monitoring requirements and inspection limitations are to be considered in choosing FRPs in lieu of conventional repairs.

For additional maintenance guidelines contact the Main Office Bridge Maintenance Program Engineer.

DESIGNER INSTRUCTIONS:

Due to the wide variety of material types, and since their design and manufacture depends on the desired structural performance to be achieved, specifications are performance based. Many systems are patented and the Contractor will require the services of the FRP manufacturer or supplier. Specifications require the Contractor's supplier to design the FRP repair to the loads, capacities and service life shown on the contract plans. The FRP system and materials must appear on the Department's Approved List of Materials and Equipment. Calculations and working drawings are required to be submitted to the Deputy Chief Engineer (Structures) for approval.

Designers must show the required increased moment and shear capacities to be achieved for the components in question or, in the case of column wrapping, the confinement force and the minimum design life (if less than 20 years) on the contract plans. The FRP manufacturer's engineer will design the FRP repair materials to meet these requirements. The designer should compute the additional strength required over the capacity of the existing concrete section. In the case of flexural members, designers should not attempt to require the FRP material to totally replace the strength of the effective existing steel reinforcement. This will likely result in an impractical design. In all cases, designers shall not specify overly high reinforcement capacities to be carried by the FRP material as this would likely result in a non-ductile failure mechanism for the structural element. This is likely to be a concern if the reinforced capacity of the element is more than 125% of the original capacity. Designers are referred to ACI 440, Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures, for recommended design procedures for FRP's applied to concrete structures.

MONITORING:

The monitoring effort will vary depending on the expected service life and type of application. For all applications a visual inspection, including soundings, shall be performed within 3 to 4 months after installation to verify adequate placement. Inspections should typically be done by Regional or Structures Division staff involved with the design, but could be incorporated into biennial bridge inspections. All inspections shall be documented using the attached form.

Recommended inspection intervals are:

Confinement repairs (contact critical) - initial inspection in 3-4 months, subsequent inspections every 2 years.

Strengthening repairs (bond critical) - initial inspection in 3-4 months, subsequent inspections in 9 to 10 months and then every 2 years.

FRP repairs are still in the trial phase. Existing applications have been monitored for four years or less. For this reason, a limited number of projects may be approved. At present, consultation and approval of the Main Office Structures Division is required to determine if the use of FRP materials are appropriate.

Questions regarding this SDA shall be directed to the Structures Division Standards Unit at (518) 485-1148.

FRP Installation/Inspection Report

INSTALLATION

Date of Installation:
BIN:
Region:
County:
Featured Carried:

Installation By: G Maintenance Forces
G Contractor

Type of Installation: G Bond Critical (Strengthening)
G Contact Critical (Confinement)
G Maintenance

FRP Supplier:
FRP System:

Description of Application:

INSPECTION

Date of Inspection:
Inspected By (Name):
Affiliation of Inspector:

Inspection Techniques Used: G Visual
G Acoustic Sounding (coin or hammer)
G Ultrasonic
G Thermographic
G Mechanical (pull off tension test)

Comments:

Recommendations:

Copies of completed form are to be sent to the Regional Structures Engineer and the Deputy Chief Engineer Structures at the Main Office Structures Division.